NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WEATHER PROGRAMS

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office has continued to improve NASA's weather support capabilities for both manned and unmanned space launch vehicles. It is expected that these improvements will strengthen and enhance the information provided to the ground-based decision makers and astronaut observers to insure that NASA achieves the best operational posture for Space Shuttle launches and landings. The goal of the operations program is to provide the specialized meteorological data needed by operational forecasters at the Kennedy Space Center (KSC) and Johnson Space Center (JSC). NASA also maintains a sophisticated fleet of eighteen Earth-monitoring satellites, measuring a vast number of Earth properties. The focus of Earth Science Research is to integrate satellite observations, numerical model and theoretical studies of various Earth system attributes. These attributes include ocean currents, temperature and biological activity; atmospheric ozone and aerosols; tropical rainfall, lightning; atmospheric temperature and humidity structure; Antarctic and Arctic sea ice; volcanic emissions and gravitational anomalies in the Earth's crust. NASA also performs aviation research to improve safety, develop weather information technologies, and increase aviation system capacity. Advanced operations technologies can increase the number of operations per runway in all weather conditions. The research applies to both commercial and general aviation.

THE NASA VISION:

To improve life here,
To extend life to there,
To find life beyond.

THE NASA MISSION:

To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
...as only NASA can.

SUPPORTING RESEARCH: NASA'S SCIENCE MISSION DIRECTORATE (SMD).

NASA transformed its organization in the summer of 2004, uniting the former Earth and Space Science Enterprises. The Science Mission Directorate will carry out the scientific exploration of the Earth, Moon, Mars and beyond; chart the best route of discovery; and reap the benefits of Earth and space exploration for society. A combined organization is best able to establish an understanding of the Earth, other planets and their evolution, bring the lessons of our study of Earth to the exploration of the Solar System, and to assure the discoveries made here will enhance our work there.

The frontier of Earth system science is to:

(1) explore interactions among the major components of the Earth system - continents, oceans, atmosphere, ice, and life;

(2) distinguish natural from human-induced causes of change; and

(3) understand and predict the consequences of change.

Within the Science Mission Directorate, NASA has established six scientific focus areas for these complex processes. These scientific focus areas are: Atmospheric Composition, Carbon Cycle and Ecosystems, Climate Variability and Change, Earth Surface and Interior, Water and Energy Cycle, and Weather. Roadmaps have been developed to summarize the technology, observations, modeling, field campaigns, basic research, and partnerships needed over the next 25 years to achieve the long-term goals for each of these focus areas.

The availability of fresh water on planet Earth affects billions of people. Floods and drought can be life-threatening. The following questions guide research within the Water and Energy Cycle Focus Area:

- How are global precipitation, evaporation, and the cycling of water changing?
- What are the effects of clouds and surface hydrologic processes on Earth's climate?
- How are variations in local weather, precipitation and water resources related to global climate variation?
- How will water cycle dynamics change in the future?

The Water and Energy Cycle Focus Area studies the distribution, transport, and transformation of water and energy within the Earth system. Since solar energy drives water and energy exchanges, the energy cycle and the water cycle are intimately entwined. Thus, research focuses on the closely linked budgets of energy and moisture. Focus area research is aligned with national and international programs including the Global Energy and Water Cycle Experiment and the water cycle activities of the U.S. Climate Change Science Program.

The approach to these goals rests on a combination of observations, understanding, modeling, prediction, and decision-support systems presented in the Water and Energy Cycle Roadmap. This integrated approach will yield improved overall knowledge of the water cycle and improved predictions of the changing of the water and energy cycles. Future missions on the roadmap will provide key measurements for this focus area including: soil moisture, ocean water storage and flux, global precipitation, groundwater storage, tropospheric water storage, and atmospheric water and energy storage.

Precipitation has only recently been measured from space by the Tropical Rainfall Measuring Mission. The Global Precipitation Measurement (GPM) mission will extend remote sensing of precipitation globally, allowing estimation of this input term in Earth's water budget. Evaporation cannot be measured directly, but can be estimated using models based on estimates of the amount of radiation absorbed by the land, oceans, and atmosphere and validated using selected satellite measurements including ocean salinity from Aquarius and soil moisture from HYDROS. The Water and Energy Cycle Focus Area concentrates on storage as soil moisture, ground water, surface water, and snow.

Weather has enormous influence on human activities. Favorable weather is in many cases critical for agricultural productivity while severe weather can disrupt virtually every enterprise and endanger human life, property, and natural resources. Accurate weather prediction allows preparation for severe events and adaptation to day-to-day variations. Accurate hurricane predictions as well as tornado tracking save lives and property. Agriculture, transportation systems, and numerous other endeavors all rely on weather forecasts for daily decisions and resource allocation.

The direct question, "How can weather forecast duration and reliability be improved?" guides research within NASA's Weather Focus Area.

The Weather Focus Area seeks to apply NASA remote sensing expertise to obtain accurate and globally-distributed measurements of the atmosphere for assimilation into operational weather forecast models thereby improving and extending weather predictions.

Accurate local and regional predictions begin with global simulations. These simulations require the assimilation of satellite measurements of the atmosphere in depth for the entire globe. NASA develops the satellite sensors for sounding the atmosphere's temperature and humidity structure. The latest high-accuracy sensor is the AIRS instrument on board the Aqua satellite. AIRS data are being studied intensely for inclusion into operational processing streams.

Currently, high priority is assigned to the detection and quantification of rainfall rate, generally measured by microwave remote sensing. Surface radars have long been able to estimate rainfall rate, with the assumption of appropriate drop-size distributions and a national network of Doppler radars estimate the locations of wind velocity couplets that signal likely tornado formation. NASA's first weather radar in space, TRMM, enabled global rainfall mapping throughout the seasons increased our understanding of storm-cloud characteristics accompanying various forms and levels of rainfall rates. Extension of satellite weather radar to a global constellation of active and passive sensors can pave the way for future operational missions.

In order to provide a near-real time global view of rainfall, which can be used to monitor regions for the effects of drought and flood, NASA operates the TRMM-based Multi-satellite Precipitation Analysis (MPA). The product is updated every three hours and is publicly available at http://trmm.gsfc.nasa.gov. The MPA is a quasi-global precipitation analysis at fine time and space scales (3-hr, 0.25 degree by 0.25degree latitude-longitude) over the latitude band 50 degree N-S (Figure 3-NASA-1). This analysis

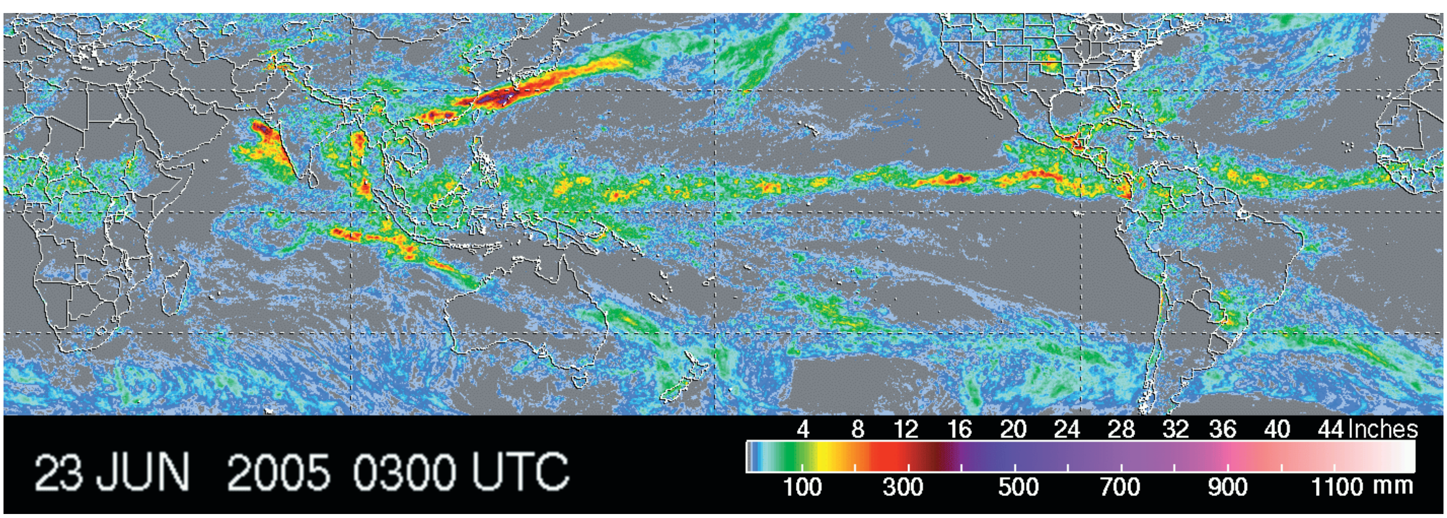

Figure 3-NASA-1. Global view of one week of rainfall accumulation obtained by the TRMM-based Multi-Satellite Precipitation Analysis.

scheme makes use of TRMM's highest quality, but infrequent observations, along with high quality passive microwave-based rain estimates from 3-7 polar-orbiting satellites, and even estimates based on the five geosynchronous IR data covering the tropics. The technique uses as much microwave data as possible, including data from Aqua/AMSR and SSM/I's and AMSU's on operational satellites, and only uses the geo-IR estimates to fill in remaining gaps in the three-hour analysis.

Other NASA weather research is important for the design of new satellite sensors for cloud and rainfall characteristic measurement and focused field programs help researchers to understand the natural variability and structure of the atmosphere, clouds, and storms on finer and finer scales as the numerical models are able to handle the higher-resolution data.

Another key component of the current Weather Focus Area is a set of core efforts to assimilate new NASA satellite data into numerical forecast models and to assess the amount of forecast improvement. Two groups are currently working on this problem, the Joint Center for Satellite Data Assimilation and NASA's Short-term Prediction Research and Transition Center. These centers allow studies of the most effective ways of assimilating new satellite data into global and regional numerical models.

The centerpiece of NASA's Earth Observing System is a sophisticated fleet of eighteen Earth-monitoring satellites, measuring a vast number of Earth properties (Figure 3-NASA-2). The focus of Earth science research is to integrate satellite observations, numerical model and theoretical studies of various Earth system attributes. These attributes include ocean currents, temperature and biological activity; atmospheric ozone and aerosols; tropical rainfall, lightning; atmospheric temperature and humidity structure; Antarctic and Arctic sea ice; volcanic emissions and gravitational anomalies in the Earth's crust. Not all of these measurements are currently being assimilated into numerical forecast models to determine their potential forecast impacts. As basic research concerning scales of variability and physical relationships to other parts of the Earth System is completed, additional EOS data products will be tested for forecast improvement potential.

In addition to precipitation measurement, important new satellite missions to advance weather forecast accuracy include an operational surface moisture monitor, geostationary monitoring of lightning location, strength, and rate, and the global monitoring of vector wind fields through out the depth of the atmosphere. Perhaps the greatest value for a future satellite sensor to would be the implementation of a fleet of Doppler lidar sensors to measure global winds as a function of height.

HIGHLIGHT: NASA SHEDS LIGHT ON HURRICANE BIRTH PROCESS

Severe tropical storms in the form of hurricanes pose a serious hazard to citizens in the eastern United States. In recent years, NASA has made strides in investigating the structure and behavior of tropical cyclones. The new insights into the nature of these deadly storms have come from a multi-pronged approach, fusing Earth Observing System (EOS) datasets with a comprehensive series of aircraft missions called the Convection and Moisture Experiment (CAMEX), and numerical modeling studies. Comprehensive datasets collected from space and in the field have provided many intriguing insights into the processes that govern hurricane growth and evolution. Numerical modeling investigations take the analyses a step further by assimilating diverse observational datasets into a theoretical framework for performing experiments.

The Tropical Cloud Systems and Processes (TCSP) mission is a field research investigation sponsored by the Science Mission Directorate of the National Aeronautics and Space

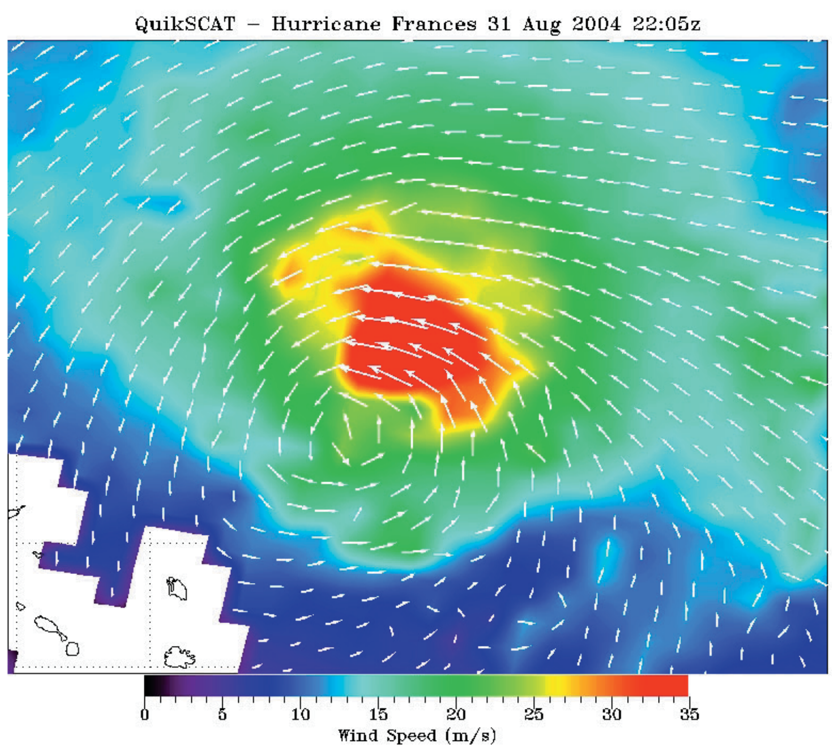

Figure 3-NASA-2. NASA QuickSCAT satellite view of Hurricane Frances (2004) in the Atlantic, showing structure of the low-level wind vortex.

Administration (NASA). The field experiment will run from July 1-28, 2005 and is based out of San Jose, Costa Rica. TCSP builds on the success of previous Convection and Moisture Experiment (CAMEX) missions. The focus of TCSP will be to better understand the complex and myriad processes giving rise to the birth of tropical cyclones over the Eastern Pacific.

TCSP research will address the following topical areas:

1) tropical cyclone structure, genesis, intensity change, moisture fields and rainfall;

2) satellite and aircraft remote sensor data assimilation and validation studies pertaining to development of tropical cyclones; and

3) the role of upper tropospheric/lower stratospheric processes governing tropical cyclone outflow, the response of wave disturbances to deep convection and the evolution of the upper level warm core. Analyses of data sets will address a wide variety of atmospheric space and time scales, ranging from the convective through the synoptic. Investigations will also be conducted to improve upon numerical modeling studies of tropical cyclogenesis, including wave-to-depression transition in the western Caribbean, Gulf of Mexico and Eastern Pacific Oceans (Figure 3-NASA-3).

NASA's ongoing partnership with NOAA's Hurricane Research Division (HRD) during the CAMEX campaigns will continue during TCSP. Two NOAA P-3 aircraft will base out of Costa Rica and fly with the NASA ER-2 high-altitude research aircraft during coordinated missions into developing tropical disturbances. The benefits of scientific collaboration between NASA and NOAA are profound; NOAA aircraft fly in the lower and middle regions of the storm, while NASA aircraft obtain data from the upper region. Together, an entire three dimensional structure of the hurricane can be assessed from the ocean surface all the way into the lower stratosphere.

NASA WEATHER OPERATIONS.

The goal of the NASA weather operations program is to provide specialized meteorological data and techniques needed by Air Force forecasters (45th Weather Squadron (45WS)) at Cape Canaveral Air Force Station (CCAFS), adjacent to Kennedy Space Center (KSC), and by the NWS's Spaceflight Meteorology Group (SMG) at Johnson Space Center (JSC), to support NASA's Space Shuttle and Expendable Launch Vehicle (ELV) programs. Their greatest challenge is to accurately measure and forecast the mesoscale weather events that strongly impact ground processing, launch, and landing operations.

Note: 45WS supports ground processing and launch of Shuttle and ELV's at KSC/CCAFS, and Shuttle Ferry Flight missions. SMG supports Shuttle flight; landing at KSC, Edwards AFB and White Sands Space Harbor; as well as emergency landing sites worldwide.

To successfully support the diverse, unique and complex requirements of their many customers' 24/7 operations, in the mesoscale driven lightning capital of America, requires:

1. A sophisticated weather infrastructure which includes systems normally found only in research field programs rather than operations;

2. A dedicated capability to transition research and technology to support new or poorly satisfied operational requirements;

3. Rigorous training to ensure the weather infrastructure, diverse customer requirements, and dynamic, mesoscale weather are thoroughly understood; and

4. At least 2-3 years on-site experience to adequately master the infrastructure, the weather, and the requirements sufficiently to provide timely, tailored, accurate support to the many weather sensitive daily operations.

SUPPORTING RESEARCH

<u>Applied Meteorology Unit</u>.

The focal point for satisfying requirement three above and assisting with requirements one and two is the Applied Meteorology Unit (AMU). The AMU, co-located with the Air Force's Range Weather Operations at CCAFS, develops, evaluates and, if warranted, transitions new meteorological technology into operations. For instance, the AMU strives to develop techniques and systems to help predict and avoid the impacts of Central Florida's frequent thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program-Space Shuttle, DOD, and commercial entities. The AMU has focused special attention on evaluating and transitioning mesoscale numerical models, and developing forecast techniques appli-

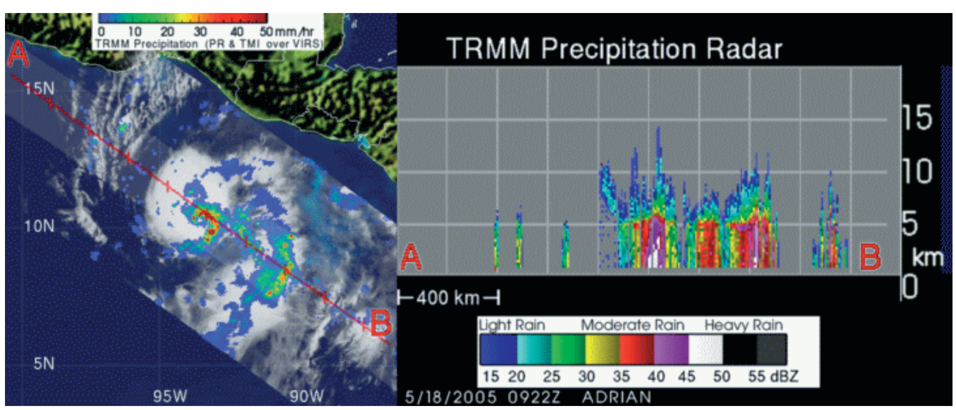

Figure 3-NASA-3. NASA TRMM satellite view of the rain structure in Tropical Storm Adrian (2005) in the eastern Pacific.

cable to Central Florida. The AMU functions under a joint NASA, Air Force, and National Weather Service (NWS) Memorandum of Understanding.

Current AMU tasks and status as of June 05 include:

Task: Objective Lightning Probability Forecast: Phase I

Goal: Develop a set of statistical equations to forecast the probability of lightning occurrence for the day. This will aid forecasters in evaluating flight rules and determining the probability of launch commit criteria violations, as well as preparing forecasts for ground operations.

Discussion: The 45th Weather Squadron (45 WS) forecasters include a probability of thunderstorm occurrence in their daily morning briefings. This information is used by managers for daily planning, especially for lightning sensitive ground operations on Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS) requiring long lead times or many hours to complete. Much of the current lightning probability forecast is based on a subjective analysis of model and observational data. The forecasters requested development of a lightning probability forecast tool based on statistical analyses of historical warm-season data--a tool to increase the objectivity of daily thunderstorm probability forecasts.

The AMU developed a statistical lightning forecast equations that will provide a lightning occurrence probability for the day by 1100 UTC (0700 L) during the months May - September (warm season). The tool is based on results from several research projects. Tests of the equations show they improve the daily lightning forecast, thus the AMU developed a PC-based tool and GUI from which forecasters can display the daily probabilities. As the GUI was tested, graphs were created that showed the change in probability due to changes in one predictor while holding all other predictors constant. These graphs show the users how sensitive the output probabilities are to changes in one predictor value versus changes in the others.

Three of the data types used to develop the technique were:

Cloud-to-Ground Lightning Surveillance System data,

1200 UTC sounding data from synoptic sites in Florida, and

1000 UTC CCAFS sounding (XMR) data.

The AMU used the CCAFS (XMR) sounding data to calculate the stability parameters normally available to the forecasters through the Meteorological Interactive Data Display System (MIDDS). MIDDS uses the Man-computer Interactive Data Access System (McIDAS) software (Lazzara et al. 1999) for processing and displaying the sounding data. The McIDAS algorithms that process the sounding data used in this task ensured the calculated stability parameter values will be consistent with those available to the forecasters. *Note: The AMU worked with the vendor to correct errors discovered in the COTS algorithms before proceeding with this task.*

Task: Severe Weather Forecast Decision Aid

Goal: Create a new forecast aid to improve the severe weather watches and warnings meant for the protection of KSC) and CCAFS personnel and property.

Discussion: The 45WS morning weather products includes an assessment of the likelihood of local convective severe weather in order to enhance protection of personnel and material assets of the 45th Space Wing, CCAFS, and KSC. Severe weather includes tornadoes, wind gusts 50 kt, and/or hail with a diameter of 0.75 in. Forecasting the occurrence and timing of these phenomena is challenging for 45WS duty forecasters and Launch Weather Officers.

The AMU developed a new severe weather forecast decision aid tuned to the east-central Florida environment to improve the various 45WS severe weather watches and warnings. The decision aid will provide severe weather guidance for the day by 1100 UTC (0700 EDT). The analyses of cumulative distributions of rawinsonde-based stability parameters were used to re-assess the threshold values currently used by 45WS. The AMU recommended adjustments to the threshold values based on the historical severe weather events in east-central Florida and the accompanying stability indices from the morning CCAFS rawinsonde. The AMU archives of severe weather events, stability indices, and synoptic characterizations of atmospheric flow patterns were merged for further analysis.

The display used to evaluate the stability indices was changed from scatter plots to stacked column graphs, providing a different perspective on the relationships between the indices and severe weather. An interactive web-based severe weather forecast tool was developed and delivered to the 45WS for initial evaluation.

With the new graphs, some of the indices show stronger relationships to severe weather occurrence. Specific index thresholds and other criteria were incorporated into the severe weather forecast tool which is now ready for forecaster testing during the upcoming warm season.

Task: Shuttle Ascent Camera Cloud Obstruction Forecast

Goal: Develop a model to forecast the probability at least three Shuttle ascent imaging cameras can view the Shuttle launch vehicle (LV) unobstructed by cloud at any time from launch to Solid Rocket Booster (SRB) separation.

Discussion: Optical imaging of the Shuttle launch vehicle (LV) from ground-based and airborne cameras is susceptible to obstruction by clouds. The Columbia Accident Investigation Board (CAIB) recommended the Shuttle ascent imaging network be upgraded to have the capability of providing at least three useful views of the LV from lift-off to SRB separation. In response, the NASA/KSC Weather Office tasked the AMU to develop a model to forecast the probability cloud will not obstruct the view of at least X imaging cameras at any time from launch to SRB separation. An analysis of the sensitivity of viewing probabilities to upgrades of the camera network was developed in collaboration with the Shuttle Launch Director, the KSC Intercenter Photo Working Group, and the 45WS Shuttle Launch Weather Officer.

A 3-D computer model was randomly seeded with cloud fields and viewing probabilities were computed for selected cloud scenarios. The AMU model was based on computer simulations of:

1. idealized, random cloud coverage scenarios;
2. the optical lines-of-sight from cameras to the LV using the camera network before and after upgrades for Return to Flight (RTF); and
3. a LV ascent trajectory for a launch from Pad 39B to the International Space Station (ISS). Based on the results, launch day criteria and launch decision strategies are being developed and coordinated with senior Shuttle management.

Task:Stable Low Cloud Evaluation

Goal: Examine archived data collected during rapid stable cloud development events resulting in cloud ceilings below 8000 ft at the Shuttle Landing Facility (SLF). Document the atmospheric conditions favoring this type of cloud development to improve the ceiling forecast issued by the SMG for Shuttle landings at KSC.

Milestones: Identified days in the time period 1993 - 2003 that had low-level temperature inversions and cloud ceilings below 8000 ft. Retrieved visible satellite images from those same days for comparison.

Discussion: Approximately 25 days of satellite images were retrieved from the satellite database and loaded onto the AMU weather display systems. These images were analyzed to identify days with rapid low cloud development.

Task: Hail Index

Goal: Evaluate current techniques used by the 45WS to forecast the probability of hail occurrence and size. Hail forecasts are required to protect personnel and material assets at KSC, CCAFS, Patrick Air Force Base and the Melbourne International Airport. The evaluation results will be used by the 45WS to determine if a new technique is needed.

Milestones: The AMU used data from the Cloud-to-Ground Lightning Surveillance System (CGLSS) to evaluate the Neumann-Pfeffer Thunderstorm Index (NPTI) technique, as the hail size forecast generated by the computer code is contingent on a "yes" thunderstorm forecast by the NPTI.

Discussion: On 966 days with lightning activity in the local area as indicated by CGLSS, the NPTI forecast a "yes" on only 511 days. This level of performance suggests that the computer code should be modified to generate a forecast hail size independent of the NPTI forecast.

Task: RSA and Legacy Wind Sensor Evaluation

Goal: Compare wind speed and direction statistics from the legacy and RSA sensors on the Eastern (ER) and Western (WR) Ranges to determine the impact of the sensor changes on wind measurements. The 45WS and 30WS (Vandenberg AFB, CA) need to know of any differences in the measurements between the two systems as they use these winds to issue weather advisories for operations.

Milestones: Analyzed 4 hours of archived RSA and legacy wind data from Tower 300 on the WR on a day with northeast winds at 10 to 20 kts.

Discussion: The average wind speeds and directions were similar for both instruments but the RSA peak speeds were several knots higher than the legacy gusts. A study using synthetic data showed that the algorithm used to calculate the legacy peak speeds likely caused a large percentage of the difference. However, these results have limited utility as the archived gusts are not used to evaluate Launch Commit Criteria (LCC). Efforts are underway to obtain the legacy peak speed data used to evaluate LCC during launch operations. *Note: The KSC Weather Office and the AMU believe the algorithm is faulty*

Task: Volume Averaged Height Integrated Radar Reflectivity (VAHIRR)

Goal: Transition the VAHIRR algorithm into operations. The current lightning launch commit criteria (LLCC) for anvil clouds to avoid triggered lightning are overly conservative and lead to costly launch delays and scrubs. The VAHIRR algorithm was developed as a result of the Airborne Field Mill program to evaluate a new LLCC for anvil clouds. This algorithm will assist forecasters in providing fewer missed launch opportunities with no loss of safety compared with the current LLCC.

Milestones: The VAHIRR algorithm was acquired from the National Center for Atmospheric Research.

Discussion: The VAHIRR algorithm was received and installed on a local computer for development. There were also several discussions with Mr. Tim Crum and Mr. Randy George of the Radar Operations Center in Norman, OK on the process of integrating new algorithms into the WSR-88D operational system.

Task: Mesoscale Model Phenomenological Verification Evaluation

Goal: Find model weather-phenomena verification tools in the literature that could be transitioned into operations. Forecasters use models to aid in forecasting weather phenomena important to launch, landing, and daily ground operations. Methods that verify model performance are needed to help forecasters determine the model skill in predicting certain phenomena.

Milestones: Collected journal articles describing the development and/or use of new phenomenological verification techniques. Created tables containing information about each technique.

Discussion: The tables include the article reference, weather phenomenon being verified, model being verified, model and observational data used, name of the new technique, and the feasibility of transitioning the technique to operations.

Task: ARPS Optimization and Training Extension

Goal: Provide assistance and support for upgrading and improving the operational Advanced Regional Prediction System (ARPS) and ARPS Data Analysis System (ADAS) that is used to make operational forecasts at the National Weather Service in Melbourne, FL (NWS MLB) and SMG forecast offices.

Milestones: Completed the upgrade of the operational ADAS to software version 5.1.2 at the NWS MLB, and created a data-conversion program to process Automated Surface Observing System (ASOS) data.

Discussion: The upgrade and installation of ADAS onto the new Linux workstation at the NWS MLB was completed. A new data-ingest program was written to improve the ADAS analysis quality at off-hour times by incorporating ASOS observations. The AMU also corrected an erroneous specification of soil type over the Bahamas and improved the terrain resolution.

Task: User Control Interface for ADAS Data Ingest

Goal: Develop a GUI to help forecasters at NWS MLB and SMG manage the data sets assimilated into the operational ADAS.

Milestones: Completed installation of GUI at NWS MLB.

Discussion: A fully functional ADAS control GUI was installed at NWS MLB following trouble-shooting of certain map background issues

Task: Anvil Transparency Relationship to Radar Reflectivity

Goal: Determine if the NWS MLB WSR-88D radar can be used to analyze anvil cloud transparency.

Discussion: Anvil cloud transparency is an important element in forecasting triggered lightning launch commit criteria. Opaque anvils can carry an electrical charge. If a vehicle flies through such a charge, it could trigger lightning and be destroyed. The AMU identified 45 days during summer 2003 with thunderstorm anvil cirrus clouds over the KSC Shuttle Landing Facility weather observation site (KTTS), based on a comparative analysis of satellite imagery and the KTTS observations.

The NOAA Radar Operations Center is processing the WSR-88D Layer Reflectivity Maximum products for the 45 case days. These will be used in a comparative analysis with the surface observations of anvil transparency from KTTS.

Task: Range Standardization and Automation (RSA) Support

Goal: Help Eastern Range personnel evaluate proposed designs and implementations of the weather systems upgrade by the RSA and SLRSC contractors. AMU participates in design reviews, acceptance tests and other functions as required.

OTHER KENNEDY SPACE CENTER SUPPORTING RESEARCH

Lightning Launch Commit Criteria (LLCC) [Airborne Field Mill (ABFM)] Program

The KSC Weather Office continued to direct the analysis of data gathering from KSC's major field research program called the Lightning Launch Commit Criteria (LLCC) program. The LLCC program used an aircraft equipped with field mills and cloud physics sensors, in combination with several ground based radars and other sensors, to collect the data necessary to relax the lightning launch constraints while making them even safer. LLCC was cooperatively funded by the Shuttle program, NASA ELVs and the USAF. The team included more than 50 personnel from eleven organizations including other Governmental agencies, NASA Centers, universities and their contractors.

Based on analyses of the extensive data base of in-situ and radar measurements, the team developed revised LLCC for both Attached Anvils and Detached Anvils. Working with colleagues from the National Center for Atmospheric Research (NCAR), Marshall Spaceflight Center (MSFC), the University of Arizona (U AZ), the Hurricane Research Division (NOAA/HRD), National Severe Storms Lab., Aerospace Corp. and others, KSC developed and applied software to perform a variety of analyses on the massive data set. These analyses included correlation and power spectral analyses, and extensive statistical examinations of the radar, cloud physics and electric field data.

KSC facilitated and participated in defining the new LLCC. To help the Lightning Advisory Panel (LAP) determine the threshold electric field aloft that poses a triggered lightning hazard, KSC acquired information from Shuttle and Titan about the length of the ionized plum from their solid rocket motors. From data obtained elsewhere on the likely potential difference required to trigger lightning, the LAP used the plume lengths to convert the triggering threat potential to a corresponding threshold electric field.

In order to automate processing of ABFM data for the determination of the decay of electric fields with distance from cloud edges, KSC developed an automated cloud edge detection algorithm. A paper describing the algorithm and its testing appeared in the May 2004 issue of the Journal of Atmospheric and Oceanic Technology. (Ward, J.G. and F.J. Merceret, 2004: An Automated Cloud-Edge Detection Algorithm Using Cloud Physics and Radar Data, J. Atm. & Ocean. Tech., 21(5), 762-765)

Winds

The KSC Weather Office (KSCWO) requested the Shuttle Program to reexamine its day of launch upper air winds procedures to ensure spatial and temporal variability are being optimally accounted for. The KSCWO presented several briefings on temporal wind persistence as a function of vertical feature size and related instrumentation matters to the Space Shuttle Natural Environments Panel challenging engineers from the Shuttle, Titan and new Expendable Launch Vehicle programs (Atlas V and Delta IV) to reconsider their assumptions and launch day procedures.

OPERATIONS

In addition to Supporting Research, the KSC Weather Office continues to work with the Eastern Range (ER) to improve the KSC and ER weather infrastructures and improve operational processes and facilities.

Visibility Sensors.

In FY2004, KSC began transmitting Visibility and Soil Moisture data to JSC/SMG from five suites of newly installed sensors west of KSC to aid in the forecast of morning fog that could impact Shuttle landings.

Range Standardization and Automation (RSA)

The KSC Weather Office, SMG at JSC, and the AMU continue to actively participate in plans and proposals for projects managed by the RSA program. RSA is a major Air Force program to modernize the Eastern and Western Range infrastructures. Many issues remain with RSA's pending changes. Thus, the Air Force and NASA weather communities continued to expend significant resources to solve potential major RSA deficiencies, since NASA KSC, JSC and MSFC depend heavily on this infrastructure for their weather support. A major success was the RSA contractor's decision to discard their proposed Control and Display (C&D) system, and instead partner with NOAA's Forecast Systems Lab to deliver a COTS AWIPS (Automated Weather Information System). This will provide Range Weather Operations with a very capable system that is cost effective, and compatible with both future AWIPS upgrades and with SMG. However, in FY 2003 and FY 2004 Air Force budget redirection seriously threatened cancellation of the entire RSA weather system which would have seriously degraded long term weather support to the American Space Program. Fortunately, the program is still progressing. Although deliveries of some weather sensors, models, and control and display systems began in FY2000, budget restrictions have delayed full operational capability and acceptance by the Eastern Range to FY 2007 (a decade plus delay from original schedule).

Spacelift Range Systems Contract (SLRS-C)

In addition to the RSA Modernization programs, the new SLRS-C provides Sustaining Engineering for the legacy systems and also the systems RSA is delivering. SLRS-C is currently upgrading or replacing three systems currently owned by NASA Kennedy Space Center:

- 50 MHz Doppler Radar Wind Profiler,
- Shuttle Landing Facility Weather Tower and Sensor system, and
- the Lightning Detection and Ranging (4D total lightning) system. Upon completion of each program, the system will be turned over from NASA/KSC to the Eastern Range. Despite numerous logistical and programmatic hurdles all three programs will likely succeed:
- SLF in FY 2006,
- 4D lightning in FY 2007, and
- 50 MHz profiler in FY 2007.

50 MHz Doppler Radar Wind Profiler (DRWP)

Replacement of many KSC DRWP and its electronic components components began in FY 2004 and finished in FY 2005. Meanwhile, several antenna field issues were corrected,

1. The Air Force funded a project to improve the drainage of the DRWP antenna field that flooded during very heavy rains.
2. During droughts, the very dry antenna ground plane caused erroneous side lobe returns. The Profiler O&M contractor designed and a contractor installed a sprinkler system to wet the antenna field during droughts. The sprinkler system is now installed which solved the side-lobe problem during dry weather.

Shuttle Landing Facility (SLF) Weather Sensors

SLRSC also contracted to replace and modernize all SLF weather instrumentation. SLRS-C chose the AF Weather Agency FMQ-19 as the basic system to ensure adequate logistics support. To meet special NASA requirements, the system has been modified to provide 1 second winds, additional ceilometers off both runway approaches, and a 120 minute (vs 30 minute) UPS backup. After several communication links are complete, the system will become operational and turned over to the AF expected by FY 2006.

Lightning Detection and Ranging (LDAR) System.

Since LDAR was originally developed as a research system in the late 80's, its components are increasingly subject to obsolescence, thus costs and the risk of system failure are increasing. KSC worked with the Range to justify raising the priority of a replacement LDAR in the AF Space Command priority list. The AF and KSC worked with SLRS-C to overcome numerous obstacles: electromagnetic interference; NASA and AF requirements vs. COTS capabilities; site selection for antenna towers; takeover of COTS contractor by Finish international company; etc. Major unresolved KSC issues: transmission of LDAR data to SMG and NWS Melbourne; and an expected requirement to perform environmental impact assessments (EIS) on all seven antenna sites because of the location of two towers in marshlands. The EISs will delay antenna installation until FY 2006; testing until FY 2006, and project completion until FY 2007.

TAL Atmospheric Sounding System (TASS).

The Radio Automatic Theodolite System (RATS) was used to provide SMG with upper level winds, temperatures and humidity at the Shuttle Transatlantic Abort Landing (TAL) sites in Spain, Morocco, and Gambia. RATS became obsolete when the manufacturer announced cessation of sonde production. A replacement system called TASS, a Global Positioning System (GPS) based Sippican W9000, was selected, procured, integrated and tested with the help of the Eastern Range. The initial system is now installed and operational. The Eastern Range owns, operates and maintains the system for NASA. In order to improve TASS' user friendliness, reliability, and accuracy, NASA will funded the ER to upgrade the Operating System from DOS to Windows, and upgrade the sondes in FY 2005.

Sonic Lightning Locator (SOLLO).

The KSC Weather Office funded development of a new lightning detection system capable of locating lightning strikes in 4D with an accuracy of <5 meters (a considerable improvement over the 250-300 meter accuracy of our current lightning location system.). Called SOLLO, it uses a sensor to detect the time of arrival of the electromagnetic pulse from a lightning strike, and then one elevated detector and three surface based detectors to measure the time of arrival of thunder from the lightning, to very accurately calculate the location of the lightning strike. SOLLO also calculates the amperage, rise time, and polarity of the strike. During FY 2004, KSC replaced/upgraded SOLLO components to enhance its capability to operate reliably in the corrosive KSC/ER environment. During the 2004 and 2005 spring/summer lightning season, KSC installed SOLLO systems at the Shuttle Launch Complex and a new technology development and testing facility for further testing.

KSC/CCAFS Weather Observation Site Relocation.

The 24/7 official KSC/CCAFS Weather Observation Site is located in a very aging structure with its view of Shuttle Landing Facility (SLF) runway totally obscured. We convinced architects and managers of a project to build a new SLF air traffic control tower to include two floors for weather observers and equipment. The Range Technical Service Contractor (CSR) provided detailed specifications to ensure the final design met strict observing requirements. The tower project is complete; and move in was completed in FY 2005. The tower enables observers to provide much more accurate weather depictions over SLF, especially during rapidly changing conditions, thus improving aircraft, Space Shuttle and future RLV safety.

Lightning Launch Commit Criteria (LLCC) Revision

During analyses of Airborne Field Mill (ABFM) Program data, the Lightning Advisory Panel (LAP) concluded the radar definition of cloud edge, top and base in the LLCC was not sufficiently conservative. Based on ABFM measurements of electric fields high enough to trigger lightning with radar reflectivities as low as 5 dBZ, the LAP concluded the radar threshold needed to be lowered from10 dBZ to 0 dBZ. The conclusion was reached one week before the launch of first Mars Rover on board a Delta.

A new definition was quickly staffed from the LAP thru 45WS and 45th Space Wing Safety, and the revision recommended at the Delta/Mars Rover Launch Readiness Review two days before launch. Although Launch and Program managers are normally reluctant to accept last minute changes to procedures, we emphasized the revision was a safety issue and they accepted the change exactly as proposed.

Columbia Accident Investigation

The entire NASA and Eastern Range weather communities (KSC, JSC/SMG, MSFC, GSFC, LRC, and 45WS) were deeply involved supporting the Space Shuttle Columbia accident investigation. Weather analyses were crucial to: identifying likely debris impact locations over the western and central United States; characterizing the atmosphere during reentry, beginning in the very data sparse upper Mesosphere; identifying possible anomalous wind shears during launch ascent; analyzing Columbia's exposure to the atmosphere during the 39 days Columbia was on the launch pad; and numerous engineering studies. NOAA/NWS also provided considerable help.

Helios Accident Investigation

NASA's premier solar-powered research aircraft (Helios) crashed just west of Barking Sands, Kauai in late June 2003. The KSC Weather Office participated on the Mishap Board along with Dr. John Brown from NOAA/Forecast Systems Lab. Due to Helios' many unique design and power characteristics, it had many very complex stability and control physics and characteristics.

Initial research revealed little was known about the atmosphere's behavior west of Kauai, specifically the atmosphere's combined response to the wake turbulence from the Trade Wind flow over the island, shear lines from air flowing around Kauai, sea breezes, and the large scale pattern. Thus the Weather Office contracted with NCAR (Dr. Bob Sharman) and the University of Hawaii (Dr. Duane Stevens) to perform high resolution atmospheric numerical model simulations to try to understand the atmosphere Helios encountered. In addition, the University of Hawaii designed and implemented a very low budget, aircraft data gathering program offshore of Barking Sands, Kauai to measure wind and temperature profiles, and turbulence features. We used the aircraft data to understand small-scale features and to validate results from NCAR's high resolution model simulations. The final Helios Mishap Board report was released to the public.

BUDGET

Budget changes from FY 2005 to FY 2006 for core O&M capabilities are mostly due to inflation with two exceptions.

1. The funds transferred to Eastern Range for weather support began to increase in FY 2005 as NASA returned to launching Shuttles after 2 ½ years of analyses and program changes following the Columbia accident.

2. A $200K increase in the FY 2005 budget to O&M the LDAR and DRWP systems. Both are R&D systems developed in the late 1980's which are now used to support operations. Their components are rapidly becoming obsolete and hard/expensive to replace. The AF expects to replace LDAR by FY 2006 and DRWP by late FY 2005, and then assume system ownership from NASA. Meanwhile O&M costs will continue to escalate.

Three significant programs required large budget outlays/commitments:

1. Shuttle Landing Facility (SLF) weather system (replacement),

2. 4D Lightning Detection and Ranging (LDAR) (replacement), and

3. 50 MHz Doppler Radar Wind Profiler (DRWP) (upgrade).

The AF is funding a significant portion of and managing the programs. Estimated costs are: SLF: $1.8M; LDAR: $2.6M; and DRWP $3+M. NASA's contributions are to satisfy unique NASA requirements and to facilitate the modernization and system transition to the AF.